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Validation study of fatty acid consumption assessed with a short food frequency questionnaire against plasma concentration in middle-aged Japanese people

Chiho Goto[1], Yuko Tokudome[1], Nahomi Imaeda[2], Kiyoshi Takekuma[3], Kiyonori Kuriki[4], Fukuyo Igarashi[5], Masato Ikeda[6] and Shinkan Tokudome[7]

[1]Department of Health and Nutrition, School of Health and Human Life, Nagoya-bunri University, Inazawa, Japan; [2]Nagoya Women's University, Mizuho-ku, Nagoya, Japan; [3]Aichi Prefectural Health Promotion Center, Ohbu, Japan; [4]Division of Epidemiology and Prevention, Aichi Cancer Center Research Institute, Chikusa-ku, Nagoya, Japan; [5]Suzuka University of Medical Science, Suzuka, Japan; [6]University of Occupational and Environmental Health, Yahatanishi-ku, Kitakyushu, Japan; [7]Department of Health Promotion and Preventive Medicine, Nagoya City University Graduate School of Medical Sciences, Mizuho-ku, Nagoya, Japan

Abstract

Objective: To assess the relative validity of data for consumption of fatty acids (FAs) measured with a short food frequency questionnaire (FFQ) in comparison with plasma concentration of FAs.

Design: In this cross-sectional study, completed FFQs were secured from 177 (92 male and 85 female) employees working for a company in August 2001. Intake of FAs was assessed with the FFQ, and the values were validated against FA concentration in plasma in overnight-fasting blood.

Results: Mean $\pm$SD daily intakes of total fatty acids (TFAs) were 44.4 ± 8.0 g day^{-1} for men and 42.9 ± 7.2 g day^{-1} for women. Plasma concentration of TFAs were 12.73 ± 3.78 mmol l^{-1} for men and 10.54 ± 1.75 mmol l^{-1} for women. Spearman's rank correlation coefficients, unadjusted and energy-adjusted by the energy-density method and residual method, for n-3 highly unsaturated fatty acids (HUFAs) were 0.37 ($p < 0.001$), 0.38 ($p < 0.001$) and 0.40 ($p < 0.001$) for men, and 0.41 ($p < 0.001$), 0.26 ($p < 0.01$) and 0.29 ($p < 0.01$) for women, respectively.

Conclusions: Relative validity values of data for intake of n-3 polyunsaturated fatty acids (PUFAs) for women and n-3 HUFAs in both genders, assessed with the FFQ compared with FA concentration in plasma, were moderate, but no significant associations were found for saturated fatty acids, monounsaturated fatty acids or n-6 PUFAs.

Keywords: *fatty acids*; *food frequency questionnaire*; *plasma concentration*; *relative validity*

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Introduction

Morbidity and mortality associated with chronic diseases such as cancer, cerebrovascular disorders and heart disease are major public health concerns not only in developed countries but also in the developing world (1, 2). These are related to our daily lifestyle, including dietary habits, smoking, alcohol drinking, physical exercise and stress. Smoking appears to be the most potent single factor, the association with disease being unequivocal. Food consumption also seems to play a significant role, but observations are inconsistent, so further research on the relationships between consumption of particular foods/nutrients and health/disease is required.

Controversial findings may depend on the fact that information on dietary intake is not necessarily valid or reproducible owing to several factors

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related to individual variation, the time frame and the questionnaire applied (3–5). The development of food frequency questionnaires (FFQs)/semi-quantitative food frequency questionnaires (SQFFQs), relative validity and reproducibility deserve special attention because they are often used to measure habitual dietary consumption for case–control and cohort studies.

The present group evolved a data-based self-administered brief FFQ with a multiple regression analysis to secure information on the long-term intake of foods and nutrients (6). When this was applied to the general populace in a relative validity study versus three-day weighed diet records (3d-WDRs), moderate correlations, as reported elsewhere (7), and fairly high reproducibility were obtained (in preparation). The present study validated the consumption of fatty acids (FAs) measured with the FFQ against FA concentration in plasma, because intake of fats/oils and fat energy percentage have recently attracted increasing attention as risk factors for diseases, including metabolic syndrome and malignant neoplasia.

Subjects and methods

Subjects

At an annual health check-up program at a company in August 2001, 217 participants among 519 employees gave written informed consent to this study. Of these, 40 were excluded because they either had eaten breakfast or were suffering from lifestyle-related diseases, including diabetes mellitus, hyperlipidemia, nephritis, hypertension or hyperthyroidism. One hundred and seventy-seven (92 men and 85 women) remained as the subjects for the present investigation. The participants had already completed the short FFQ during a week prior to the health check-up and unanswered items were checked at the examination site. Overnight fasting venous blood was then sampled.

Short food frequency questionnaire

The FFQ inquired about habitual dietary intake of 47 foods/food groups, including rice, bread and noodles (three items), margarine/butter (two), eggs (one), milk and dairy products (two), soybean and soybean products (three), miso-soup (one), meat including beef, pork and chicken (four), fish (three), other fish, shellfish and fish products (four), green–yellow vegetables (five), other vegetables and mushrooms (three), edible roots (four), seaweeds (one), mayonnaise (one), fried dishes (two), seeds (one), fruit (two), beverages, including alcohol (three), and confectionery (two), during the preceding year, with intake frequency in eight categories (6). Portion/serving size for Japanese staple foods, including rice, noodles and bread, major sources of most nutrients, was also queried.

Analysis of fatty acids

The sum of the following 13 FAs was used for total FAs (8): 14:0 (myristic acid), 16:0 (palmitic acid), 16:1 (palmitoleic acid), 18:0 (stearic acid), 18:1 (oleic acid), 18:2 (n-6) (ω6) (linoleic acid, LA), γ-18:3 (n-6) (γ-linonenic acid), α-18:3 (n-3) (ω3) (α-linolenic acid, ALA), 20:3 (n-6) (dihomo-γ-linonenic acid), 20:4 (n-6) (arachidonic acid, AA), 20:5 (n-3) (icosapentaenoic acid, IPA), 22:5 (n-3) (docosapentaenoic acid, DPA) and 22:6 (n-3) (docosahexaenoic acid, DHA). The selected 13 FAs accounted for $94.6 \pm 7.7\%$ in men and $96.0 \pm 8.2\%$ in women of total FAs.

For saturated fatty acids (SFAs) the sum of 14:0 + 16:0 + 18:0, for monounsaturated fatty acids (MUFAs) the sum of 16:1 + 18:1, for n-6 polyunsaturated fatty acid (PUFAs) the sum of 18:2 n-6 + 18:3 n-6 + 21:3 n-6 + 22:3 n-6, and for n-3PUFAs the sum of 18:3 n-3 + 20:5 n-3 + 22:5 n-3 + 22:6 n-3 were obtained. For n-3 highly unsaturated (long-chain ω3) fatty acids (HUFAs) the sum of 20:5 (n-3) + 22:5 (n-3) + 22:6 (n-3) was chosen.

FA concentration (mmol l^{-1}) in whole lipids were analyzed by gas chromatography at a commercial laboratory (9). The intra-assay coefficients of variation were distributed from 2.1% [for 22:6 (n-3)] to 4.2% (for 14:0) and inter-assay coefficients of variation being from 2.8% (for 18:0) to 7.7% [for 22:5 (n-3)]. Minimal detection values were distributed from 0.004 mmol l^{-1} (for 14:0, 16:0 and 16:1) to 0.03–0.04 mmol l^{-1} [for 22:5 (n-3) and 22:6 (n-3)].

Calculation of consumption of fatty acids

The average daily intake of FAs (g day^{-1}) was computed using the information from the FFQ. Because a multiple regression analysis was applied to the development of the questionnaire (4, 10, 11), the selected FAs were used as dependent parameters. Independent variables were the foods/food groups consumed, intake frequency, portion size (in grams) from the FFQ for staple foods or a database

(8, 12) or typical/standard values from the literature for other foods (13–15), and FA contents per 100 g of foods/food groups listed in the respective composition tables or of the model recipes.

Statistical analysis

Since the FFQ was evolved according to a multiple regression model, we computed Spearman's rank correlation coefficients, instead of Pearson's correlation coefficients, for relative validity indices between intake of the selected FAs (g day^{-1}) assessed with FFQ and plasma concentration of FAs (mmol l^{-1}).

Unadjusted Spearman's rank correlation coefficients were calculated between consumption of FAs and FA concentration in plasma. Two energy-adjusted Spearman's rank correlation coefficients were computed: consumption of FAs per 1000 kJ of energy (g 1000 kJ^{-1}) (energy-density method) and consumption of FAs according to the residual method versus plasma concentration of FAs (4). Selected FA compositions by weight percentage of TFAs in dietary consumption were compared with those in plasma concentration.

All statistical analyses were performed using SAS software (16) and $p < 0.05$ was considered statistically significant.

Results

Characteristics of the study subjects

Daily intakes of energy were 7920 ± 1343 and 6343 ± 820 kJ day^{-1} for men and women, respectively (Table 1). Fat intakes were 47.5 ± 10.5 and 45.2 ± 9.3 g day^{-1} and fat-energy percentages were $23.0 \pm 5.8\%$ and $27.0 \pm 4.9\%$, for men and women, respectively.

Table 1. Characteristics of the study subjects

	Men ($n = 92$)	Women ($n = 85$)
Age (years)	44.3 ± 9.9	40.4 ± 9.0
Body height (m)	1.71 ± 0.64	1.58 ± 0.51
Body weight (kg)	69.7 ± 9.2	51.4 ± 6.6
Body mass index (kg m^{-2})	23.8 ± 2.7	20.6 ± 2.3
Current smokers, *n* [%]	40 [43.5]	1 [1.2]
Intake of macronutrients		
Energy (kJ day^{-1})	7920 ± 1343	6343 ± 820
Protein (g day^{-1})	61.3 ± 11.1	52.4 ± 8.3
Total fat (g day^{-1})	47.5 ± 10.5	45.2 ± 9.3
Carbohydrate (g day^{-1})	267.0 ± 61.1	210.7 ± 33.4
% Energy from		
Protein	13.0 ± 1.7	13.9 ± 1.6
Total fat	23.0 ± 5.8	27.0 ± 4.9
Carbohydrate	55.9 ± 6.1	55.5 ± 4.4
Frequency of fish consumption (days $week^{-1}$)	3.2 ± 2.1	3.3 ± 1.9
Serum lipids		
Total cholesterol (mmol l^{-1})	5.13 ± 0.79	4.86 ± 0.81
HDL-cholesterol (mmol l^{-1})	1.63 ± 0.28	1.87 ± 0.27
Triglycerides (mmol l^{-1})	1.51 ± 1.05	0.75 ± 0.35

Data are shown as mean ± SD.
HDL: high-density lipoprotein.

Consumption of fatty acids

Daily intakes of TFAs were 44.4 ± 8.0 and 42.9 ± 7.2 g day^{-1} for men and women, respectively (Table 2). Daily intakes of SFAs were 12.2 ± 2.6 and 11.8 ± 2.5 g day^{-1}, MUFAs 17.5 ± 3.8 and 16.9 ± 3.5 g day^{-1}, and PUFAs 14.7 ± 3.2 and 14.2 ± 2.8 g day^{-1} for men and women, respectively.

Plasma concentration of fatty acids

Plasma concentration of TFAs were 12.73 ± 3.78 mmol l^{-1} and 10.54 ± 1.75 mmol l^{-1} for men and women, respectively. The plasma concentration of SFAs were 4.09 ± 1.39 and 3.25 ± 0.69 mmol l^{-1}, MUFAs 3.34 ± 1.33 and 2.51 ± 0.51 mmol l^{-1}, and PUFAs 5.30 ± 1.17 and 4.77 ± 0.70 mmol l^{-1} for men and women, respectively.

Correlation between consumption of fatty acids and plasma concentration

Spearman's rank correlation coefficients, unadjusted and energy-adjusted by the energy-density method and the residual method, for n-3 PUFAs were 0.00, 0.01 and 0.00 for men and 0.22 ($p < 0.05$), 0.12 and 0.17 for women, respectively (Table 3). For n-3 HUFAs, they were 0.37 ($p < 0.001$), 0.38 ($p < 0.001$) and 0.40 ($p < 0.001$) for men and 0.41 ($p < 0.001$), 0.26 ($p < 0.01$) and 0.29 ($p < 0.01$) for women, respectively. No significant correlations were observed for TFAs, SFAs, MUFAs and n-6 PUFAs.

Discussion

In the authors' earlier report, average daily intake of macronutrients and micronutrients could be reasonably assessed with the short FFQ versus 3d-WDRs administered to the public populace (7). In the present study, validity indices for consumption of FAs estimated with the FFQ in comparison with plasma concentration of FAs, irrespective of un-

Table 2. Comparison of fatty acid consumption assessed with the food frequency questionnaire versus plasma concentration

	Dietary consumption (g day^{-1})		Plasma concentration (mmol l^{-1})	
	Men (n=92)	Women (n=85)	Men (n=92)	Women (n=85)
TFAs	44.4±8.0	42.9±7.2	12.73±3.78	10.54±1.75
SFAs	12.2±2.6	11.8±2.5	4.09±1.39	3.25±0.69
MUFAs	17.5±3.8	16.9±3.5	3.34±1.33	2.51±0.51
PUFAs	14.7±3.2	14.2±2.8	5.30±1.17	4.77±0.70
n-6 PUFAs	12.3±2.7	11.9±2.6	4.29±0.93	4.00±0.58
n-3 PUFAs	2.4±0.5	2.4±0.5	1.00±0.36	0.77±0.22
n-3 HUFAs	0.8±0.3	0.7±0.3	0.87±0.32	0.68±0.21

Data are shown as mean±SD.

TFAs: total fatty acids; SFAs: saturated fatty acids; MUFAs: monounsaturated fatty acids; PUFAs: polyunsaturated fatty acids; HUFAs: highly unsaturated fatty acids.

adjusted or energy-adjusted procedures adopted, were moderate for n-3 PUFAs in women and n-3 HUFAs in both genders, but no significant correlations were found for TFAs, SFAs, MUFAs or n-6 PUFAs. These findings were compatible with those of earlier observations applying an SQFFQ to Japanese female dietitians (17, 18). Thus, the FFQ may be applied to the general populace to assess consumption of n-3 PUFAs and n-3 HUFAs, in particular, and to rank the subjects according to their dietary intake of FAs.

There are several reasons why relative validity indices for FFQs may be generally low. The questionnaire was relatively short and 47 foods/food groups do not seem to provide sufficient coverage for all FAs. A questionnaire asking about dietary consumption of FAs over one year may not be compatible with FA concentration in plasma because Japanese people enjoy different foods/food groups in different seasons (19). It must be assumed that public people's memory and cognition are not infallible and human error invariably occurs in dietary studies. Naturally, the relative validity values in the authors' experience using the short FFQ versus 3d-WDRs administered to the general populace gave lower figures, as a whole (7), than those observed in the investigation using the SQFFQ covering 102 foods/food groups versus 28d-WDRs applied to Japanese female dietitians (8).

The nature of FA concentration in plasma should also be discussed. Biomarkers are exact because they are free from information bias largely derived from human cognition and memory, and the values have small coefficients of variation and high reproducibility. For detecting medium- to long-term consumption of FAs, homogenized whole bodies can be used with animal experimentation, whereas whole lipids (17, 18, 20–24), red blood cell membranes (25–27), colon membranes and adipose tissues (25, 28–32) have been sampled for human studies. Plasma concentration of FAs, however, does not always indicate long-term habitual intake; rather, it reflects dietary consumption in the preceding week. There are effects of homeostasis and conversion/mobilization, i.e. intake, absorption, metabolism, distribution and excretion.

Essential FAs, including LA, AA (downstream of LA) and ALA, must be obtained from the diet. The first two, however, are ubiquitously present in staple foods, including rice, cereals, noodles and bread, eggs, vegetables and vegetable oils (33), and it is hard to assess precise intake on the basis of a short FFQ. SFAs are endogenously produced and MUFAs are efficiently utilized as energy. ALA, a major component of n-3 PUFAs, also exists ubiquitously in various foods but rapidly disappears from plasma. This may explain why the validity figures for FAs, including SFAs, MUFAs and n-6 PUFAs, were not statistically significant and those for n-3 PUFAs were rather low, which were consistent with previous findings using an SQFFQ in Japanese female dietitians (17, 18). The relative validity indices for n-3 HUFAs, in particular, were moderate, which may be due to the fact that they are typically provided by marine foods (18, 20–23) and were readily assessed with the questionnaire.

In conclusion, relative validity values for n-3 PUFAs and n-3 HUFAs, in particular, with

Table 3. Spearman's rank correlation coefficients between fatty acid (FA) consumption assessed with the food frequency questionnaire and plasma FA concentration

	Men ($n=92$)	Women ($n=85$)
Between unadjusted FAs consumption (g day^{-1}) and plasma FAs concentration (mmol l^{-1})		
TFAs	−0.20	0.00
SFAs	−0.09	0.08
MUFAs	−0.16	−0.07
PUFAs	−0.16	0.00
n-6 PUFAs	−0.15	−0.04
n-3 PUFAs	0.00	0.22*
n-3 HUFAs	0.37***	0.41***
n-6 PUFAs/n-3 PUFAs ratio	0.43***	0.37***
PUFAs/SFAs ratio	0.04	−0.03
Between energy-adjusted FAs consumption by energy-density method (g 1000 kJ^{-1}) and plasma FAs concentration (mmol l^{-1})		
TFAs	−0.25*	0.07
SFAs	−0.20	0.14
MUFAs	−0.18	−0.06
PUFAs	−0.18	0.07
n-6 PUFAs	−0.18	0.07
n-3 PUFAs	0.01	0.12
n-3 HUFAs	0.38***	0.26**
Between energy-adjusted FAs consumption by residual method (g day^{-1}) and plasma FAs concentration (mmol l^{-1})		
TFAs	−0.25*	0.06
SFAs	−0.14	0.14
MUFAs	−0.17	−0.06
PUFAs	−0.18	0.04
n-6 PUFAs	−0.18	0.04
n-3 PUFAs	0.00	0.17
n-3 HUFAs	0.40***	0.29**
Between FA compositions by weight percentage of TFAs in dietary consumption (g day^{-1}) and plasma concentration (mmol l^{-1})		
SFAs	0.13	0.01
MUFAs	0.22*	0.11
PUFAs	0.03	−0.03
n-6 PUFAs	0.16	0.14
n-3 PUFAs	0.39***	0.21
n-3 HUFAs	0.58***	0.38***

***: $p<0.001$, **: $p<0.01$, *: $p<0.05$.

TFAs: total fatty acids; SFAs: saturated fatty acids; MUFAs: monounsaturated fatty acids; PUFAs: polyunsaturated fatty acids; HUFAs: highly unsaturated fatty acids.

the FFQ appear moderate, but no significant correlations were found for SFAs, MUFAs or n-6 PUFAs. However, this does not necessarily mean that the validity of the questionnaire is unacceptably low, because the two batteries detected different profiles. Strengths and weaknesses must be taken into account when administering questionnaires in large-scale case–control and cohort studies. Further studies are needed to determine the relative validity of consumption of FAs assessed with the FFQ versus compositions in red blood cell membranes or fatty connective tissues, because they may reflect long-term dietary intake of FAs better than FA concentration in plasma.

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References

1. IARC/IACR. Cancer incidence in five continents. Vol. VIII. IARC Sci Publ No 143. IARC; 2002.
2. World Cancer Research Fund/American Institute for Cancer Research. Food, nutrition and the prevention of cancer: a global perspective. Washington, DC: American Institute for Cancer Research; 1997.
3. Thompson FE, Byers T. Dietary assessment resource manual. J Nutr 1994; 124: S2245–317.
4. Willett W. Nutritional epidemiology, 2nd edn. New York: Oxford University Press; 1998.
5. Margetts BM, Nelson M. Design concepts in nutritional epidemiology. Oxford: Oxford University Press; 1999.
6. Tokudome S, Goto C, Imaeda N, Tokudome Y, Ikeda M, Maki S. Development of a data-based short food frequency questionnaire for assessing nutrient intake by middle-aged Japanese. Asian Pacific J Cancer Prev 2004; 5: 40–3.
7. Tokudome Y, Goto C, Imaeda N, Hasegawa T, Kato R, Hirose K, et al. Relative validity of a short food frequency questionnaire for assessing nutrient intake versus three-day weighed diet records in middle-aged Japanese. J Epidemiol 2005; 15: 135–45.
8. Tokudome S, Imaeda N, Tokudome Y, Fujiwara N, Nagaya T, Sato J, et al. Relative validity of a semi-quantitative food frequency questionnaire versus 28 day weighed diet records in Japanese female dietitians. Eur J Clin Nutr 2001; 55: 735–42.
9. Special Reference Laboratory. Test directory 2002. Tokyo: Special Reference Laboratory; 2002.
10. Armitage P, Berry G. Statistical methods in medical research. 3rd edn. Oxford: Blackwell Scientific Publications; 1994.
11. Mark SD, Thomas DG, Decarli A. Measurement of exposure to nutrients: an approach to the selection of informative foods. Am J Epidemiol 1996; 43: 514–21.
12. Imaeda N, Tokudome Y, Fujiwara N, Nagaya T, Kamae M, Tsunekawa S, et al. Data checking and standardiza-

tion in a weighed food dietary record survey. Jpn J Nutr 2000; 58: 67–76. (In Japanese)
13. Science and Technology Agency, Japan. Standard tables of food composition in Japan. 4th edn. Tokyo: Ministry of Finance; 1982. (In Japanese)
14. Science and Technology Agency, Japan. Standard tables of food composition in Japan. 5th edn. Tokyo: Ministry of Finance; 1993. (In Japanese)
15. Science and Technology Agency, Japan. Follow-up of standard tables of food composition in Japan. Tokyo: Ishiyaku Shuppan; 1992. (In Japanese)
16. SAS Institute. SAS/STAT user's guide, Version 8. Cary, NC: SAS Institute; 1999.
17. Kuriki K, Nagaya T, Imaeda N, Tokudome Y, Fujiwara N, Sato J, et al. Discrepancies in dietary intakes and plasma concentration of the respective FAs of fatty acids according to age among Japanese female dietitians. Eur J Clin Nutr 2002; 55: 735–42.
18. Kuriki K, Nagaya T, Tokudome Y, Imaeda N, Fujiwara N, Sato J, et al. Plasma concentration of the respective FAs of (n-3) highly unsaturated fatty acids are good biomarkers of relative dietary fatty acids intakes: a cross-sectional study. J Nutr 2003; 133: 3643–50.
19. Tokudome Y, Imaeda N, Nagaya T, Ikeda M, Fujiwara N, Sato J, et al. Daily, weekly, seasonal, within- and between-individual variation in nutrient intake according to four season consecutive 7 day weighed diet records in Japanese female dietitians. J Epidemiol 2002; 12: 85–92.
20. Bjerve KS, Brubakk AM, Fougner KJ, Johnsen H, Midthjell K, Vik T. Omega-3 fatty acids: essential fatty acids with important biological effects, and serum phospholipid fatty acids as markers of dietary ω3-fatty acid intake. Am J Clin Nutr 1993; 57(Suppl): S801–6.
21. Andersen LF, Solvoll K, Drevon CA. Very-long-chain n-3 fatty acids as biomarkers for intake of fish and n-3 fatty acid concentrates. Am J Clin Nutr 1996; 64: 305–11.
22. Hjartåker A, Lund E, Bjerve KS. Serum phospholipid fatty acid composition and habitual intake of marine foods registered by a semi-quantitative food frequency questionnaire. Eur J Clin Nutr 1997; 51: 736–42.
23. Kobayashi M, Sasaki S, Kawabata T, Hasegawa K, Tsugane S, JPHC Study. Validity of a self-administered food frequency questionnaire used in the 5-year follow-up survey of the JPHC Study Cohort I to assess fatty acid intake: comparison with dietary records and serum phospholipid level. J Epidemiol 2003; 13: S64–81.
24. Rohrmann S, Klein G. Validation of a short questionnaire to qualitatively assess the intake of total fat, saturated, mono-unsaturated, polyunsaturated fatty acids, and cholesterol. J Human Nutr Diet 2003; 16: 111–7.
25. Feunekes GIJ, van Staveren WA, de Vries JHM, Burema J, Hautvast JGAJ. Relative and biomarker-based validity of a food-frequency questionnaire estimating intake of fats and cholesterol. Am J Clin Nutr 1993; 58: 489–96.
26. Parra MS, Schnaas L, Mevdani M, Perroni E, Martinez S. Erythrocyte cell membrane phospholipid levels compared against reported dietary intakes of polyunsaturated fatty acids in pregnant Mexican women. Public Health Nutr 2002; 5: 931–7.
27. Katan MB, van Birgelen A, Deslypere JP, Penders M, van Staveren WA. Biological markers of dietary intake, with emphasis on fatty acids. Ann Nutr Metabol 1991; 35: 249–52.
28. Knutsen SF, Fraser GE, Beeson WL, Lindsted KD, Shavlik DJ. Comparison of adipose tissue fatty acids with dietary fatty acids as measured by 24-hour recall and food frequency questionnaire in Black and White Adventists: the Adventist Health Study. Ann Epidemiol 2003; 13: 119–27.
29. Garland M, Sacks FM, Colditz GA, Rimm EB, Sampson LA, Willett WC, et al. The relation between dietary intake and adipose tissue composition of selected fatty acids in US women. Am J Clin Nutr 1998; 67: 25–30.
30. Tjønneland A, Overvad K, Thorling E, Ewertz M. Adipose tissue fatty acids as biomarkers of dietary exposure in Danish men and women. Am J Clin Nutr 1993; 57: 629–33.
31. van Staveren WA, Deurenberg P, Katan MB, Burema J, de Groot LCPGM, Hoffmans MDAF. Validity of the fatty acid composition of subcutaneous fat tissue microbiopsies as an estimate of the long-term average fatty acid composition of the diet of separate individuals. Am J Epidemiol 1986; 123: 455–63.
32. Wolk A, Furuheim M, Vessby B. Fatty acid composition of adipose tissue and serum lipids are valid biological markers of dairy fat intake in men. J Nutr 2001; 131: 828–33.
33. Tokudome Y, Imaeda N, Ikeda M, Kitagawa I, Fujiwara N, Tokudome S. Foods contributing to absolute intake and variance in intake of fat, fatty acids and cholesterol in middle-aged Japanese. J Epidemiol 1999; 9: 78–90.

Dr Shinkan Tokudome
Department of Health Promotion and Preventive Medicine
Nagoya City University Graduate School of Medical Sciences
Mizuho-ku
Nagoya 467-8601
Japan.
Tel: +81 52 853 8174
Fax: +81 52 842 3830
E-mail: tokudome@med.nagoya-cu.ac.jp